EXPRESS MAIL LABEL NO. EV 321 688 393 US
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TITLE

[0001] ALCOHOL ENHANCED ALTERNATIVE FUELS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of co-pending and co-owned U.S. Provisional Patent Application Serial No. 60/433,339 filed December 13, 2003 which is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

[0002] The disclosure herein relates to improved compositions of oxygenated hydrocarbon-based fuels especially suited for use in internal combustion engines and particularly to such fuels that are principally composed of blends of naphtha, alcohol, and ether components.

BACKGROUND

[0003] In recent years, rapidly increased consumption of natural petroleum products, particularly gasoline, and consequent diminution of natural petroleum reserves have become serious problems throughout the world. Conservation measures, as well as research for substitute fuels and other sources of energy, have become of paramount importance, and a wide variety of programs have been under consideration and actually commenced in order to solve these fundamental problems. Among such programs are many that deal with internal combustion engine fuels, including the search for new fuels, alteration of presently known fuels, improved fuel manufacturing processes, the development of new types of engines, and, efforts to make current engines more efficient while consuming less fuel.

[0004] However, most of the synfuels or synthetic fuels so far (mainly alcohol fuel) have not generated as much combustion power as that of gasoline, and when such synfuels could produce an equivalent level of combustion power,

a special combustion device was necessary to burn it. Thus gasoline remains the fuel utilized in most combustion engines.

[0005] A need exists for fuels which do rely less upon petroleum reserves for gasoline as a principal constituent but that are readily operable in existing combustion engines. Gasoline is derived from extracted crude oil from oil reservoirs. Crude oil can be a mixture of hydrocarbons that exist in liquid phase in underground reservoirs and remain liquid at atmospheric pressure. The refining of crude oil to create conventional gasoline involves the distillation and separation of crude oil components, gasoline being the light naphtha component. In some instances, naphtha is generated by cracking heavier naphtha components. Other methods may exist for generating light naphtha suitable for combustion.

[0006] Conventional gasoline is a complex composition of over 300 chemicals, including paraffins, olefins, alkenes, aromatics and other relatively volatile hydrocarbons, with or without small quantities of additives blended for use in spark ignition engines. The amount of benzene in regular gasoline can range from up to 3-5 percent, and the amount of sulfur to 500 ppm. Reformulated gasoline (RPG) limits the quantity of sulfur to 330 ppm and benzene to one percent, and limits the levels of other undesirable chemicals as well. The vapor pressure of reformulated gasoline, expressed as the Reid Vapor Pressure (RVP) is typically held as low as feasible in order to reduce incidental hydrocarbon emissions during gasoline storage and fueling and is generally in range from about a RVP of 8 psi (410 torr) to about 15 psi (780 torr). The RVP needs to be sufficiently high enough to allow combustion. Reid Vapor Pressure is an accepted measurement of gasoline volatility and represents the vapor pressure of the fuel at 100° F (38° C).

[0007] Typically, automotive gasoline consists of a mixture of hydrocarbons ranging from about 4 carbons (C_4) to about twelve carbons (C_{12}). The lower molecular weight fraction, such as butane isomers, is more volatile and

typical practice has been to include volatile constituents (like butane isomers) in the fuel to insure proper engine performance. This practice, however, is at best a compromise since the presence of volatiles, on the one hand, causes an undue risk of explosion during storage and handling; and the inherent evaporative end emission losses contribute to pollution. But on the other hand, volatile organic compounds have been considered necessary for good cold engine starting. Thus, a certain amount of volatile organic compounds have been constituents in gasoline. The exact amount of the volatiles may vary according to the climate where the gasoline is sold. In fact, the gasoline industry in many locations has set voluntary limits so that geographic areas will have a combustible fuel with sufficient volatility for the prevailing climate. High levels of volatile components assure satisfactory starting and warm-up at the lowest temperature expected, and lower levels of volatile components decrease the likelihood of vapor-lock in high temperature climates.

[0008] Generally conventional gasoline formulas exhibit high levels of volatiles measured in terms of RVP. Current fuels require a relatively high amount of volatile components, which raise the RVP to undesirable levels. It is highly desirable to formulate a fuel that satisfies the volatility requirements without raising or lowering the RVP to an undesirable higher or lower level.

[0009] Conventional gasoline also contains, in addition to volatile light-weight and intermediate-weight components, a heavy-weight component which, like the volatile component, is also associated with several disadvantages. For example, conventional gasoline, when used as a fuel in short stroke engines, results in incomplete combustion because there is insufficient time or temperature to burn the heavy hydrocarbon components. This results in a certain amount of gasoline being wasted and contributing to hydrocarbon pollution. Conventional gasoline of 4-12 carbon atoms (C_4-C_{12}) has too much energy in it for many conventional internal combustion engines to utilize in that if conventional internal combustion engines combusted with enough air (stoichiometric or slightly above) the engine will burn too hot or it

will produce high levels of nitrous oxide. Yet, in spite of these shortcomings, the heavy components are left in present day fuel because their presence is considered necessary to provide a fuel having suitable properties for automotive use.

[0010] The use of conventional C_4-C_{12} fuels in standard carburetor internal combustion engines often require that the volatility of the fuel be adjusted to achieve a Reid Vapor Pressure of at least 9 psi (465 torr) in the summer and 12 psi (620 torr) in the winter. If the Reid Vapor Pressure of conventional C_4-C_{12} gasoline falls below the above limits, starting and running the engine may be severely impaired.

[0011] Conventional alternatives to crude oil-derived fuels such as compressed natural gas, propane, and electricity require large investments in automobile modification and fuel delivery infrastructure, not to mention technological development.

[0012] Among such altered fuels one of the most suitable for use in internal combustion engines is gasoline containing alcohol. This is especially so since several alcohols not only have good combustion properties but are also readily available from a wide variety of sources such as, for example, starchy grains, potatoes, industrial by-products, and products of waste materials. This is particularly true with respect to ethanol, also called ethyl alcohol.

[0013] Ethanol may be biomass-derived, octane-increasing motor fuel additive. While ethanol alone has a low vapor pressure, when blended with hydrocarbons, the resulting mixture has an unacceptably high rate of evaporation, and has not been used in EPA designated ozone non-attainment areas, which include most major metropolitan areas in the United States. Similar restrictions may exist in other geographic locations throughout the world.

[0014] The use of absolute ethanol as a fuel component and octane booster in blends with gasoline has been practiced, as seen by commercial "gasohol" which consists essentially of a 90/10 volume percent blend of gasoline and absolute ethanol. However, fuel composition blends of gasoline and ethanol are very sensitive to water contamination and in general have exhibited a very limited phase stability tolerance for water, particularly at temperatures of about 0° C and below. Moreover, it is well known that such phase separation into a gasoline-rich phase and an ethanol-water phase can result in and lead to severe internal combustion engine operation problems, such as stalling, fuel-line freezing, and the like. Such phase separation probability may explain why conventional gasoline-ethanol fuel compositions are those prepared using absolute ethanol instead of hydrous ethanol. Moreover while a gasoline-ethanol fuel composition producer may take precaution to avoid phase separation and distribution of such fuel compositions, there is little, if anything, that can be done by the producer to avoid water contamination during the retail marketing and/or individual use of such fuel compositions.

[0015] Efficient combustion mixtures for internal combustion engines include gasoline in the vapor or gaseous state thoroughly mixed with adequate air to support combustion. In this condition, fuel-rich pockets, which are responsible for detonation or "knock," are eliminated and carbon deposits responsible for pre-ignition are minimized due to more complete combustion. Because detonation or pre-ignition can damage or ruin an engine, current gasoline fuels have octane boosters such as aromatic hydrocarbons and others compounds to reduce "knock." Several engines also have fuel and air intake systems which produce droplets of fuel that contribute to fuel rich pockets in the combustion chambers tending to increase engine knock. Slowing the burn with octane boosters lowers the combustion efficiency of the engine and increases the exhaust pollution. Furthermore, adding octane boosters increases the relative cost of the fuel. Therefore, it would be highly desirable to provide a high-octane fuel without octane boosters but still

having highly desirable burning characteristics without significant engine knock.

[0016] Automotive and aviation gasoline typically have an American Society for Testing and Materials (ASTM) average octane number (R + M)/2 of 80 or higher; wherein R represents the research octane number and M represents the motor octane number. Many combustion engines generally require an average octane number in excess of 85 at sea level. At higher altitudes, the required octane decreases because fuel combustion is affected by air pressure.

[0017] As employed herein "(R + M)/2" represents the fuel composition's octane number or rating which is calculated by averaging the sum of the fuel composition's research octane number, measured according to ASTM Method D2699 and its motor octane number, measured according to ASTM Method D2700. The tendency of the engine to "knock" must be compensated by increasing the octane number of the fuel.

[0018] One way to increase the octane number and reduce exhaust gas pollution includes the addition of methanol or other alcohol (also known as alkanol). However, in order to operate an internal combustion engine having spark ignition with a combustion fuel containing more than 5% by volume of methanol, vehicles having such engines have to be equipped with methanol-resistant sealing materials. This consequence has stymied alcohol-based fuels. However, current engine manufacturers use Viton® or similar resistant elastomeric materials as sealing materials. A further serious disadvantage of admixing more than 5% by volume of methanol is that in dual-fuel operation with a methanol-hydrocarbon mixture and a pure hydrocarbon mixture using conventional carburetors and injectors, the air-fuel ratio has to be adjusted so that the proportion of pollutants is kept within the exhaust limits for operation on pure hydrocarbons.

[0019] Gasoline formulas are typically blended from several refinery components. Straight-run sometimes referred to as natural gasoline is a fraction of otherwise unprocessed crude oil boiling in the gasoline range. Straight-run gasoline is not a desirable fuel on its own because its octane value is low. FCC gasoline is made in a Fluid Catalytic Cracker from the heavy portions of the crude oil. FCC gasoline has good octane, but high sulfur content. Another refinery component is a highly-aromatic material made from the C_6-C_8 fraction of crude oil referred to as reformate. Reformate has very high octane, but lots of aromatic compounds. Many aromatic compounds are suspected as carcinogens and are consequently undesirable. Still another refinery component, alkylate is a highly-branched, low-RVP material made from the C_4 fraction of crude oil or natural gas liquids. This component is a premium material as it has a high octane and a low RVP. However, capacity for refining alkylate is limited in many geographic locations throughout the world. A full-range gasoline may contain all four of the components just described.

SUMMARY

[0020] A need exists for a combustible fuel that provides many of the combustion properties of conventional gasoline without requiring significant engine modifications, and that can be stored and delivered like conventional gasoline. In order to be an advantageous alternative for gaseous alternative fuels such as methane and propane, liquid alternative fuels should also meet all requirements for "clean fuels" defined by environmental protection agencies of the country where the fuel is used. As an example, liquid alternative fuels should meet the requirements defined by the Environmental Protection Agency (EPA) in the United States or equivalent agencies in their respective countries.

[0021] Furthermore, it would be highly desirable to provide a high-octane fuel without octane boosters but still having highly desirable burning characteristics without causing significant engine knock.

[0022] In examples of the fuel blends described, a low-pollution fuel with reduced emission of air pollutants such as CO (carbon monoxide), HC (hydrocarbons not completely burned in the combustion engine), and CO_2 (carbon dioxide), exists with similar or better engine performance when compared to conventional gasoline in terms of output and fuel efficiency, and is usable in existing internal combustion engines for gasoline without the need for many if any modifications to these combustion engines

[0023] Consequently, the discovery of gasoline-alcohol fuel compositions and gasoline-oxygenated fuel compositions having improved engine performance, minimized pollution emissions, and renewable source supply are of great value.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] Figure 1 is a graph showing the relationship between engine RPM and horsepower obtained from testing a 2002 Toyota Camry with retail gasoline and the fuel blend of Embodiment 10.

[0025] Figure 2 is a graph showing the relationship between engine RPM and torque obtained from testing a 2002 Toyota Camry with retail gasoline and the fuel blend of Embodiment 10.

[0026] Figure 3 is a graph showing the relationship between engine RPM and horsepower obtained from testing a 2002 Dodge Caravan with retail gasoline and the fuel blend of Embodiment 10.

[0027] Figure 4 is a graph showing the relationship between engine RPM and torque obtained from testing a 2002 Dodge Caravan with retail gasoline and the fuel blend of Embodiment 10.

[0028] Figure 5 is a flow chart showing the steps of preparing fuel blends which include three feed stocks.

[0029] Figure 6 is a flow chart showing the steps of preparing fuel blends which include two feed stocks.

DETAILED DESCRIPTION

[0030] The present fuel blends aim to provide a low-pollution internal-combustion engine fuel that restrain the emission of air pollutants such as CO and HC and have comparable performance to conventional gasoline in terms of output and fuel efficiency, and yet are usable in existing internal combustion engines for gasoline without significant mechanical modifications.

[0031] Advantages of the disclosed fuel compositions include lower cost, increased or similar fuel economy, increased or similar engine performance, higher octane rating, and decreased exhaust emissions.

[0032] Fuel compositions described herein can utilize the straight-run gasoline as other constituents in the compositions increase the octane value of the mixture. Using the fuel in this manner allows refineries to sell other refinery components without or with less straight-run component thereby enhancing the octane rating of the other refinery components. Using the straight-run gasoline component reduces the cost of manufacturing some of the alternative fuel blends presently described.

[0033] In one example, fuel compositions are derived primarily from renewable, domestically-produced, low cost waste biomass materials such as ethanol in combination with hydrocarbon distillates. The compositions emit fewer hydrocarbons than conventional or typical reformulated gasoline to help local areas meet EPA requirements for “clean fuels,” yet, at the same time, utilize current automobile technology with little or no engine modifications. The compositions require little more than presently existing fuel delivery

infrastructure and are based on components that result in a blend that is capable of being competitively priced with conventional gasoline.

[0034] Many of the alcohols useful in the fuel blends are produced by means of a fermentation process from three basic types of agricultural raw materials, namely saccharin, starchy and cellulosic materials.

[0035] Additives may also be included in the fuel formula of the invention. These additives may include, but are not limited to corrosion inhibitors, surfactants, detergents, metal deactivators, antioxidants, fuel stabilizers, and anti-freeze components. An example a corrosion inhibitor is SPEC-AID 8Q103 available from GE Betz, Inc. The corrosion inhibitor may be applied at a volume of 25 mL SPEC-AID 8Q103 per 1000 gallons of fuel blend.

[0036] The term "alcohol" as used herein means an alcohol of the formula ROH where R can be straight-chained alkyl of from 1 to 10 carbon atoms including aliphatic primary alcohols having up to about ten carbon atoms. R can also be branched-alkyl of from 1 to 10 carbon atoms. R can still also be cyclic-alkyl of from 1 to 10 carbon atoms. Examples of such alcohols include but are not limited to methyl, ethyl, propyl, butyl, amyl, hexyl and octyl alcohols and several more alcohols. Other alcohols include branched alkanols such as 2-butanol, isobutanol, 2-methyl-1-butanol, 3-methyl-1-butanol, and mixtures thereof. A blend of any two or more of such alcohols is also encompassed by the term alcohol.

[0037] Examples of ethers that can be used may be represented by the general formula R'OR" and include the simple ethers wherein the R' and R" groups (or moieties) are alike and mixed ethers in which the R and R' groups are different. Useful ethers are those in which the R groups are alkyls having one to twelve carbon atoms. Examples of such ethers include dimethyl ether, diethyl ether, methyl ethyl ether, ethyl *t*-butyl ether, isopropyl ether, methyl propyl ether, *n*-butyl ether, *t*-butyl ether, *sec*-butyl ether, isoamyl ether, and neo-hexyl ether.

[0038] Other ethers that are useful in the fuel blends described herein include methyl *tert*-butyl ether (MTBE), ethyl *tert*-butyl ether (ETBE), isopropyl *tert*-butyl ether, *sec*-butyl *tert*-butyl ether, and *t*-amylmethyl ether (TAME).

[0039] The term naphtha (or gasoline) as used herein can refer to hydrocarbon compositions. These hydrocarbon compositions include mixtures of hydrocarbons with an atmospheric-pressure boiling range of approximately 40-205°C (100-400°F), and can be comprised of alkanes, olefins, naphthalenes, aromatics, etc.

[0040] The compositions discussed hereafter relates to improved compositions of oxygenated hydrocarbon-based fuels especially suited for use in internal combustion engines and particularly to such fuels that are principally composed of blends of naphtha, alcohol, and ether components. In many, but not necessarily all, of the examples the fuel compositions include an alcohol component, a naphtha component, and an ether component. In still other examples, the fuel compositions include an alcohol component, a naphtha component, and an aliphatic ether component. More broadly, some of the examples of fuel compositions include an alcohol component and a naphtha component.

[0041] In some examples, the compositions may include an alcohol component in the range of about 15% to about 85% by weight, a naphtha component in the range of about 12% to about 55% by weight, and an aliphatic ether component in the range of about 3% to 30% by weight.

[0042] In some examples, the alcohol component is one or more alcohols of the formula ROH and where R may be straight-chained alkyl of from 1 to 10 carbons, branched-alkyl of from 1 to 10 carbons, and cyclic alkyl of from 1 to 10 carbons. In other examples, the alcohol component may be methanol ethanol, 1-propanol, 2-propanol, butyl alcohol, isobutyl alcohol, tertiary-butyl alcohol, glycerol, and mixtures thereof. In other examples R may be alkyl of six or fewer carbons. In still other examples the alcohol component includes

mixture of ethanol and isobutanol or ethanol alone. In many but not necessarily all, the naphtha component is a mixture of hydrocarbons distilled from petroleum. In other examples, the naphtha component is a mixture of hydrocarbons distilled from other sources of hydrocarbons including coal or other known petroleum sources.

[0043] In some examples the ether component is one or more ethers of the formula R'OR" and where R' may be straight-chained alkyl of from 1 to 12 carbons, branched-alkyl of from 1 to 12 carbons, and cyclic alkyl of from 1 to 12 carbons and where R" may be straight-chained alkyl of from 1 to 12 carbons, branched-alkyl of from 1 to 12 carbons, and cyclic alkyl of from 1 to 12 carbons, and where R' and R" of said ether formula are either identical or different moieties. In other examples the ether component may be methyl ether, ethyl ether, propyl ether, butyl ether, isopropyl ether, t-butyl ether, pentyl ether, sec-butyl ether, neo-hexyl ether, and mixtures thereof. In still other examples, the ether component may be methyl-t-butyl ether, ethyl-t-butyl ether, t-amylmethyl ether, and mixtures thereof.

[0044] In still other examples of the fuel compositions the naphtha component may be in the range of 35% to 50% by weight. In other examples the naphtha component may be in the range of 35% to 40% by weight. The naphtha component can also be in the range of 43% to 48% by weight.

[0045] In more examples of the fuel compositions, the alcohol component may be in the range of 35% to 55% by weight. In other examples the alcohol component may be in the range of 60% to 65% by weight. The alcohol component may also be in the range of 5% to 20% by weight.

[0046] In still more examples of the fuel compositions the ether component may be in the range of 3% to 30% by weight.

[0047] In many, but not necessarily all, of the examples, fuel compositions have a Reid Vapor Pressure less than or equal to about 15 psi.

[0048] In more examples, the fuel compositions include naphtha in the range of between about 40% to about 49% by weight, an alcohol component that may be about 20% to about 45% by weight ethanol and about 0.1% to about 20% by weight isopropanol or isobutanol, and an ether component that may be about 0.1% to about 10% by weight methyl-t-butyl ether. In other examples, the fuel compositions include naphtha in the range of about 40% to about 49% by weight, an alcohol component that may be about 20% to about 45% by weight ethanol and about 0.1% to about 20% by weight isopropanol or isobutanol, and an ether component in the range of about 0.1 to about 10% by weight ethyl-t-butyl ether.

[0049] In one example, a fuel composition may be an alcohol component with 25% ethanol and 20% isobutanol, a naphtha component of 45% naphtha and an ether component of 10% methyl-t-butyl ether. In another example, a fuel composition may be an alcohol component of 35.2% ethanol and 13.5% isobutanol, a naphtha component 43% naphtha and an ether component of 6.5% methyl-t-butyl ether. In still another example, a fuel composition may be an alcohol component of 20% ethanol and 20% isobutanol, a naphtha component of 40% naphtha and an ether component of 20% methyl-t-butyl ether. In yet another example, a fuel composition may be an alcohol component of 20% ethanol and 20% isobutanol, a naphtha component of 40% naphtha and an ether component of 20% ethyl-t-butyl ether. In another example, a fuel composition may be an alcohol component of 40% ethanol and 15% isobutanol, a naphtha component of 40% naphtha and an ether component of 5% methyl-t-butyl ether. In yet another example, a fuel composition may be an alcohol component of 40% ethanol and 15% isobutanol, a naphtha component of 40% naphtha and an ether component of 5% ethyl-t-butyl ether. In another example, a fuel composition may be component of 35% ethanol, a naphtha component of 45% naphtha and an ether component of 20% methyl-t-butyl ether. In still another example, a fuel composition may be an alcohol component of 38% ethanol and 4% isobutanol, a naphtha component of 48% naphtha and an ether component

of 10% methyl-t-butyl ether. In still another example, a fuel composition may be an alcohol component of 37% ethanol and 13.5% isobutanol, an naphtha component of 43% naphtha and an ether component of 6.5% methyl-t-butyl ether. In yet another example, a fuel composition may be an alcohol component of 39.8% ethanol and 4.2% isobutanol, a naphtha component of 46.3% naphtha and an ether component of 9.7% methyl-t-butyl ether. In another example, a fuel composition may be an alcohol component of 39.4% ethanol and 6.2% isobutanol, a naphtha component of 45.5% naphtha and an ether component of 8.9% methyl-t-butyl ether.

[0050] In more examples, the fuel composition may include an alcohol component in the range of about 55% to about 70% by weight and a naphtha component in the range of about 30% to about 45% by weight.

[0051] In some examples, the fuel compositions include a naphtha component in the range of 35% to 40% by weight. In other examples fuel compositions include a naphtha component in the range of 43% to 45% by weight. In some examples, the fuel compositions include an alcohol component in the range of 60% to 65% by weight. In many, but not necessarily all, of the examples, fuel compositions with an naphtha component and an alcohol component have a Reid Vapor Pressure less than or equal to about 15 psi.

[0052] In one example, a fuel composition has an alcohol component of 60% ethanol and a naphtha component of 40% naphtha. In another example, a fuel composition has an alcohol component of 45% ethanol and 20% isobutanol and a naphtha component of 35% naphtha.

[0053] In more examples, the fuel composition may include an alcohol component in the range of about 30% to about 60% by weight, a naphtha component in the range of about 40% to about 55% by weight, and an aliphatic ether component in the range of about 1% to 25% by weight.

[0054] Many jurisdictions test for levels of air-borne pollutants emitted from automobiles. Test programs such as I/M 240 and ASM (Acceleration Simulation Mode) require a dynamometer to simulate actual driving conditions. A loaded mode test such as I/M 240 monitors tailpipe emissions (including oxides of nitrogen or NO_x) during a 240-second drive cycle that includes acceleration, deceleration and high-speed operation. The average composition of the exhaust gases are then tabulated and compared to the established specifications to determine if the vehicle passes or fails. The specifications are determined by each state, county or municipality, so the actual numbers differ some from one area to another.

[0055] Emissions tests using conventional gasoline and the present fuel compositions were conducted to compare pollution emissions from automobiles. A load bearing emissions test referred to as an Acceleration Simulation Mode (ASM) emissions test was performed with different fuel blends and on different vehicles. The ASM test measures automobile emissions at two throttle positions, slow idle (RPM 15 mph)) and fast idle (RPM (25 mph)). HC (total hydrocarbons), CO (carbon monoxide), O_2 (oxygen), and CO_2 (carbon dioxide) exhaust emissions were recorded with a wand-type four-gas analyzer. Each emissions test was performed in the Salt Lake City metropolitan area.

[0056] For each emissions comparison, the vehicle was tested using conventional gasoline obtained from retail outlets such as Chevron, Conoco, and Phillips 66 stations in the Salt Lake metropolitan area. After a vehicle's emissions were tested powered by commercial grade gasoline, the vehicle's fuel tank was run empty and refilled with a fuel blend of the present compositions. The vehicles were each driven for approximately 25 miles prior to emissions testing with the fuel blend.

[0057] Full range gasoline was obtained from a retail gasoline stations in the Salt Lake metropolitan area. Straight run gasoline was obtained from a feed

stock isomerization unit at the Phillips 66 Woods Cross, Utah refinery. Gasoline used in the fuel blends was obtained from a Phillips 66 refinery located at retail gasoline obtained form the Salt Lake City metropolitan area. Naphtha was obtained as VM&P Naphtha from Ashland Distribution Company in Clearfield, Utah. Emissions tests were performed on the same engine, on the same day, and within twelve hours of one another and included a fast and slow idle measurement of HC (total hydrocarbons), CO (carbon monoxide), O_2 (oxygen), NO (nitrogen oxides), and CO_2 (carbon dioxide).

[0058] Vehicles fueled with the present compositions also underwent a road test to determine qualitative driving performance. All temperatures listed are degrees Fahrenheit unless otherwise specified. In some instances, the emissions and road testing was conducted with the air conditioner operating to "stress" the car and measure emissions with a stressed engine.

[0059] The fuel blends of the present invention will be explained further by particular embodiments and test results. The blends are described with respect to their constituents as weight or volume percents. These embodiments should not be construed as limiting the scope of the invention but are described by way of describing aspects of the invention by way of examples.

[0060] Embodiment 1

[0061] A fuel blend of the following composition was made using the following constituents measured by volume percent: gasoline (FR 45%), ethanol (25%), MTBE (10%), and isobutyl alcohol (20%). The order of mixing for the blend is arbitrary.

[0062] Emissions Comparison 1

[0063] An ASM test was conducted using the fuel blend of Embodiment 1. The test was conducted on a 2002 Toyota Corolla with a 1.8L L4 EFI engine V.I.N. #: 1NXBR12E92Z653298. The air conditioner was operating during the test.

The vehicle's odometer read just over 13,000 miles. Emissions testing was conducted and the results are displayed below in Table 1.

[0064] Table 1	Embodiment 1	Conventional Gasoline
[0065] % CO_2 (15 mph)	15.1	15.1
[0066] % CO_2 (25 mph)	15.1	15.1
[0067] % O_2 (15 mph)	0	0
[0068] % O_2 (25 mph)	0	0
[0069] ppm HC (15 mph)	12	12
[0070] ppm HC (25 mph)	10	13
[0071] % CO (15 mph)	0.01	0.01
[0072] % CO (25 mph)	0.05	0.04
[0073] ppm NO (15 mph)	22	28
[0074] ppm NO (25 mph)	45	25

[0075] As can be seen from Table 1, the fuel composition of embodiment 1 performs equally or better than the conventional unleaded fuel.

[0076] The vehicle was road tested before and after emissions testing for almost 100 miles at in-town (frequent stops) and freeway driving speeds up to 85 mph (miles per hour) with no engine knock, overheating or engine misfiring. The outside air temperature while driving the Corolla averaged 91 degrees at an elevation of approximately 4600 ft. above sea level.

[0077] Emissions Comparison 2

[0078] An additional ASM test was conducted using the fuel blend of Embodiment 1. The test was conducted on a 2002 Toyota Corolla 1.8L L4 EFI engine V.I.N. #: 1NXBR12E92Z653298 without an air conditioner operating during the test. The vehicle odometer read about 13,100 miles. Emissions testing was conducted and the results are displayed below in Table 2.

[0079] Table 2	Embodiment 1	Conventional Gasoline
[0080] % CO_2 (15 mph)	15.1	15.1
[0081] % CO_2 (25 mph)	15.2	15.1
[0082] % O_2 (15 mph)	0	0
[0083] % O_2 (25 mph)	0	0
[0084] ppm HC (15 mph)	6	7

[0085]	ppm HC (25 mph)	6	5
[0086]	% CO (15 mph)	0.04	0.1
[0087]	% CO (25 mph)	0.01	0.02
[0088]	ppm NO (15 mph)	10	41
[0089]	ppm NO (25 mph)	13	1

[0090] As can be seen from Table 2, the fuel composition of embodiment 1 performs equally or better than the conventional unleaded fuel.

[0091] The vehicle was road tested before and after emissions testing for almost 100 miles at in-town (frequent stops) and freeway driving speeds up to 85 mph with no engine knock, overheating or engine misfiring. The outside air temperature while driving the Corolla averaged 91 degrees at an elevation of approximately 4600 ft. above sea level.

[0092] Emissions Comparison 3

[0093] Still another ASM Emission Test was conducted using the fuel blend of Embodiment 1. This test was conducted on a 1992 Ford Escort 1.9L L4 SFI engine V.I.N. #: 1FAPP14J0NW173515 with no air conditioner operating during the test. The vehicle odometer read 133,670 miles. Emissions testing was conducted and the results are displayed below in Table 3.

[0094] Table 3	Embodiment 1	Conventional Gasoline
[0095] % CO_2 (15 mph)	14.9	14.9
[0096] % CO_2 (25 mph)	14.9	14.9
[0097] % O_2 (15 mph)	0	0
[0098] % O_2 (25 mph)	0	0
[0099] ppm HC (15 mph)	18	34
[00100] ppm HC (25 mph)	19	59
[00101] % CO (15 mph)	0.28	0.32
[00102] % CO (25 mph)	0.23	0.41
[00103] ppm NO (15 mph)	265	222
[00104] ppm NO (25 mph)	252	161

[00105] As can be seen from Table 3, the fuel composition of embodiment 1 performs better than the conventional unleaded fuel with respect to CO and HC

emissions. However, NO emissions climbed and suggested that older cars may require some retuning to adjust for appropriate fuel combustion. Some automobiles may nevertheless not require adjustment because elevated levels of NO may still fall below cutoff level. Newer cars have onboard computers that make the necessary adjustments for best fuel consumption with lower emissions. The increase in NO emissions are thought to be attributable to the age of the vehicle in the following respects. The fuel injectors could be worn and the spark plugs and wires weak, or the fuel to air ration may have increased to a high speed lean condition, causing increased temperature in the combustion chamber. The NO emissions may be reduced by injector impulse adjustment, by computer recalibration, spark plug and wire replacement, increased gasoline or MTBE or decreasing ethanol proportion.

[00106] Embodiment 2

[00107] A fuel blend of the following composition was made using the following constituents measured by volume percent: gasoline (FR 40%) and ethanol (60%). The order of mixing for the blend is arbitrary.

[00108] Emissions Comparison 1 (Ford Escort)

[00109] Still another ASM Emission Test was conducted using the fuel blend of Embodiment 2. The test was conducted on a 1992 Ford Escort 1.9L L4 SFI engine V.I.N. #: 1FAPP14J0NW173515 with no air conditioner operating during the test. The vehicle odometer read 133,878 miles. Emissions testing was conducted and the results are displayed below in Table 4.

[00110] Table 4	Embodiment 2	Conventional Gasoline
[00111] % CO_2 (15 mph)	14.6	14.9

[00112]	% CO_2 (25 mph)	14.7	14.9
[00113]	% O_2 (15 mph)	0	0
[00114]	% O_2 (25 mph)	0	0
[00115]	ppm HC (15 mph)	16	34
[00116]	ppm HC (25 mph)	22	59
[00117]	% CO (15 mph)	0.3	0.32
[00118]	% CO (25 mph)	0.21	0.41
[00119]	ppm NO (15 mph)	262	222
[00120]	ppm NO (25 mph)	223	161

[00121] As can be seen from Table 4, the fuel composition of embodiment 2 performs better than the conventional unleaded fuel with respect to CO and HC emissions. However, NO emissions were elevated. As previously discussed, adjustments may be made to vehicles to compensate for elevated NO emissions if desired. Such adjustments would be within one skilled in the art to perform.

[00122] The vehicle was road tested before and after emissions testing at in-town (frequent stops) and freeway driving speeds up to 75 miles per hour with the air conditioner operating. No engine knock, overheating or engine misfiring was observed. The outside air temperature while driving the Escort averaged 92 degrees at an elevation of approximately 4600 ft. above sea level.

[00123] Embodiment 3

[00124] A fuel blend of the following composition was made using the following constituents measured by volume percent: gasoline (FR 43%), ethanol (35.2 %), MTBE (6.5%), isopropyl alcohol (1.8%), and isobutyl alcohol (13.5%). The order of mixing for the blend is arbitrary.

[00125] Emissions Comparison 1

[00126] An ASM Emission Test was conducted using the fuel blend of Embodiment 3. The test was conducted on a 2002 Toyota Camry 2.4L L4 EFI DOHC 16V engine V.I.N. # 4T1BE32KX2U5200144 without an air conditioner operating during the test. The vehicle odometer read just over 13,720 miles. Emissions testing was conducted and the results are displayed below in Table 5.

[00127] Table 5	Embodiment 3	Conventional Gasoline
[00128] % CO_2 (15 mph)	15.3	15.3
[00129] % CO_2 (25 mph)	15.2	15.4
[00130] % O_2 (15 mph)	0	0

[00131]	% O_2 (25 mph)	0	0
[00132]	ppm HC (15 mph)	6	4
[00133]	ppm HC (25 mph)	6	4
[00134]	% CO (15 mph)	0	0.01
[00135]	% CO (25 mph)	0	0.01
[00136]	ppm NO (15 mph)	0	0
[00137]	ppm NO (25 mph)	0	0

[00138] As can be seen from Table 5, the fuel composition of embodiment 3 performs equally or better than unleaded fuel purchased at a gas station.

[00139] The vehicle was road tested before and after emissions testing at in-town (frequent stops) and freeway driving speeds up to 95 miles per hour with the air conditioner on and off. No engine knock, overheating or engine misfiring was observed. The outside air temperature while driving the Camry averaged 100 degrees at an elevation of approximately 4600 ft. above sea level.

[00140] Emissions Comparison 2

[00141] An additional ASM Emission Test was conducted using the fuel blend of Embodiment 3. The test was conducted on a 2003 Toyota Corolla with a

1.8L L4 VVTI DOHC 16V engine V.I.N. #1NXBR32E23Z0457174 and no air conditioner operating during the test. The vehicle odometer read just over 1,920 miles. Emissions testing was conducted and the results are displayed below in Table 6.

[00142] Table 6	Embodiment 3	Conventional Gasoline
[00143] % CO_2 (15 mph)	15	15.1
[00144] % CO_2 (25 mph)	15	15.1
[00145] % O_2 (15 mph)	0	0
[00146] % O_2 (25 mph)	0	0
[00147] ppm HC (15mph)	2	0
[00148] ppm HC (25 mph)	1	0
[00149] % CO (15 mph)	0	0
[00150] % CO (25 mph)	0	0
[00151] ppm NO (15 mph)	7	3

[00152] ppm NO (25 mph)	12	9

[00153] As can be seen from Table 6, the fuel composition of embodiment 3 performs equally or better than unleaded fuel purchased at a gas station.

[00154] The vehicle was road tested before and after emissions testing at in-town (frequent stops) and freeway driving speeds up to 95 miles per hour with the air conditioner on and off. No engine knock, overheating or engine misfiring was observed. The outside air temperature while driving the Corolla averaged 100 degrees at an elevation of approximately 4600 ft. above sea level.

[00155] Emissions Comparison 3

[00156] Still another ASM Emission Test was conducted using the fuel blend of Embodiment 3. The test was conducted on a 1994 Toyota Corolla 1.8L L4 EFI engine V.I.N. # 2T1AE09B6RC069580 with no air conditioner operating during the test. The vehicle odometer read just over 131,800 miles. Emissions testing was conducted and the results are displayed below in Table 7.

[00157] Table 7	Embodiment 3	Conventional Gasoline
[00158] % CO_2 (15 mph)	12.2	14.5
[00159] % CO_2 (25 mph)	.12	14.5
[00160] % O_2 (15 mph)	3.7	0

[00161]	% O_2 (25 mph)	4	0.1
[00162]	ppm HC (15 mph)	20	30
[00163]	ppm HC (25 mph)	23	31
[00164]	% CO (15 mph)	0.02	0.31
[00165]	% CO (25 mph)	0.00	0.21
[00166]	ppm NO (15 mph)	260	489
[00167]	ppm NO (25 mph)	251	481

[00168] As can be seen from Table 7, the fuel composition of embodiment 3 performs significantly better than unleaded fuel purchased at a gas station with respect to all of the monitored emissions.

[00169] The vehicle was road tested before and after emissions testing at in-town (frequent stops) and freeway driving speeds up to 75 miles per hour with the air conditioner on and off. No engine knock, overheating or engine misfiring was observed. The outside air temperature while driving the Corolla averaged 99 degrees at an elevation of approximately 4600 ft. above sea level.

[00170] Embodiment 4

[00171] A fuel blend of the following composition was made using the following constituents measured by volume percent: gasoline (35% FR), ethanol (45%), and isobutyl alcohol (20%). The order of mixing for the blend is arbitrary.

[00172] Emissions Comparison 1

[00173] An ASM Emission Test was conducted using the fuel blend of Embodiment 4. The test was conducted on a 2002 Toyota Camry 2.4L L4 EFI DOHC 16V engine V.I.N. # 4T1BE32KX2U5200144 with an air conditioner operating during the test. The vehicle odometer read just over 11,500 miles. Emissions testing was conducted and the results are displayed below in Table 8.

[00174] Table 8	Embodiment 4	Conventional Gasoline
[00175] % CO_2 (15 mph)	15.2	15.2
[00176] % CO_2 (25 mph)	15.3	15.3
[00177] % O_2 (15 mph)	0.0	0.0
[00178] % O_2 (25 mph)	0.0	0.0
[00179] ppm HC (15 mph)	0	6
[00180] ppm HC (25 mph)	3	7

[00181]	% CO (15 mph)	0.00	0.01
[00182]	% CO (25 mph)	0.00	0.01
[00183]	ppm NO (15 mph)	0	19
[00184]	ppm NO (25 mph)	3	44

[00185] As can be seen from Table 8, the fuel composition of embodiment 4 performs significantly better than unleaded fuel purchased at a gas station with respect to all of the monitored emissions.

[00186] Embodiment 5

[00187] A fuel blend of the following composition was made using the following constituents measured by volume percent: gasoline (40% FR), ethanol (20%), MTBE (20%), and isobutyl alcohol (20%). The order of mixing for the blend is arbitrary.

[00188] Emissions Comparison 1

[00189] An ASM Emission Test was conducted using the fuel blend of Embodiment 5. The test was conducted on a 2002 Toyota Camry 2.4L L4 EFI DOHC 16V engine V.I.N. # 4T1BE32KX2U5200144 with an air conditioner operating during the test. The vehicle odometer read just over 11,500 miles. Emissions testing was conducted and the results are displayed below in Table 9.

[00190] Table 9	Embodiment 5	Conventional Gasoline
[00191] % CO_2 (15 mph)	15.2	15.2
[00192] % CO_2 (25 mph)	15.2	15.3
[00193] % O_2 (15 mph)	0	0.0
[00194] % O_2 (25 mph)	0	0.0
[00195] ppm HC (15 mph)	3	6
[00196] ppm HC (25 mph)	3	7
[00197] % CO (15 mph)	0	0.01
[00198] % CO (25 mph)	0	0.01
[00199] ppm NO (15 mph)	1	19
[00200] ppm NO (25 mph)	1	44

[00201] As can be seen from Table 9, the fuel composition of embodiment 5 performs significantly better than unleaded fuel purchased at a gas station with respect to all of the monitored emissions.

[00202] Embodiment 6

[00203] A fuel blend of the following composition was made using the following constituents measured by volume percent: gasoline (40% FR), ethanol (20%), ETBE (20%), and isobutyl alcohol (20%). The order of mixing for the blend is arbitrary.

[00204] Emissions Comparison 1

[00205] An ASM Emission Test was conducted using the fuel blend of Embodiment 6. The test was conducted on a 2002 Toyota Camry 2.4L L4 EFI DOHC 16V engine V.I.N. # 4T1BE32KX2U5200144 with an air conditioner operating during the test. The vehicle odometer read just over 11,500 miles. Emissions testing was conducted and the results are displayed below in Table 10.

[00206] Table 10	Embodiment 6	Conventional Gasoline
[00207] % CO_2 (15 mph)	15	15.2
[00208] % CO_2 (25 mph)	15.0	15.3
[00209] % O_2 (15 mph)	0.0	0.0
[00210] % O_2 (25 mph)	0.0	0.0

[00211]	ppm HC (15 mph)	1	6
[00212]	ppm HC (25 mph)	2	7
[00213]	% CO (15 mph)	0.00	0.01
[00214]	% CO (25 mph)	0.00	0.01
[00215]	ppm NO (15 mph)	0	19
[00216]	ppm NO (25 mph)	0	44

[00217] As can be seen from Table 10, the fuel composition of embodiment 6 performs significantly better than unleaded fuel purchased at a gas station with respect to all of the monitored emissions.

[00218] Embodiment 7

[00219] A fuel blend of the following composition was made using the following constituents measured by volume percent: gasoline (40% FR), ethanol (40%), MTBE (5%), and isobutyl alcohol (15%). The order of mixing for the blend is arbitrary.

[00220] Emissions Comparison 1

[00221] An ASM Emission Test was conducted using the fuel blend of Embodiment 7. The test was conducted on a 2002 Toyota Camry 2.4L L4 EFI DOHC 16V engine V.I.N. # 4T1BE32KX2U5200144 with an air conditioner operating during the test. The vehicle odometer read just over 11,500 miles.

Emissions testing was conducted and the results are displayed below in Table 11.

[00222] Table 11	Embodiment 7	Conventional Gasoline
[00223] % CO_2 (15 mph)	15.1	15.2
[00224] % CO_2 (25 mph)	15.1	15.3
[00225] % O_2 (15 mph)	0.0	0.0
[00226] % O_2 (25 mph)	0.0	0.0
[00227] ppm HC (15 mph)	1	6
[00228] ppm HC (25 mph)	1	7
[00229] % CO (15 mph)	0	0.01
[00230] % CO (25 mph)	0	0.01
[00231] ppm NO (15 mph)	2	19
[00232] ppm NO (25 mph)	4	44

[00233] As can be seen from Table 11, the fuel composition of embodiment 7 performs significantly better than unleaded fuel purchased at a gas station with respect to all of the monitored emissions.

[00234] Embodiment 8

[00235] A fuel blend of the following composition was made using the following constituents measured by volume percent: gasoline (40% FR), ethanol (40%), ETBE (5%), and isobutyl alcohol (15%). The order of mixing each material is arbitrary.

[00236] Emissions Comparison 1

[00237] An ASM Emission Test was conducted using the fuel blend of Embodiment 8. The test was conducted on a 2002 Toyota Camry 2.4L L4 EFI DOHC 16V engine V.I.N. # 4T1BE32KX2U5200144 with an air conditioner operating during the test. The vehicle odometer read just over 11,500 miles. Emissions testing was conducted and the results are displayed below in Table 12.

[00238] Table 12	Embodiment 8	Conventional Gasoline
[00239] % CO_2 (15 mph)	15.1	15.2
[00240] % CO_2 (25 mph)	15.1	15.3
[00241] % O_2 (15 mph)	0.0	0.0
[00242] % O_2 (25 mph)	0.0	0.0

[00243]	ppm HC (15 mph)	1	6
[00244]	ppm HC (25 mph)	1	7
[00245]	% CO (15 mph)	0	0.01
[00246]	% CO (25 mph)	0	0.01
[00247]	ppm NO (15 mph)	0	19
[00248]	ppm NO (25 mph)	0	44

[00249] As can be seen from Table 12, the fuel composition of embodiment 8 performs significantly better than unleaded fuel purchased at a gas station with respect to all of the monitored emissions.

[00250] Embodiment 9

[00251] A fuel blend of the following composition was made using the following constituents measured by volume percent: gasoline (45% FR), ethanol (35%), and MTBE (20%). The order of mixing for the blend is arbitrary.

[00252] Emissions Comparison 1

[00253] An ASM Emission Test was conducted using the fuel blend of Embodiment 9. The test was conducted on a 2002 Toyota Camry 2.4L L4 EFI DOHC 16V engine V.I.N. # 4T1BE32KX2U5200144 with an air conditioner operating during the test. The vehicle odometer read just over 11,500 miles.

Emissions testing was conducted and the results are displayed below in Table 13.

[00254] Table 13	Embodiment 9	Conventional Gasoline
[00255] % CO_2 (15 mph)	15.1	15.2
[00256] % CO_2 (25 mph)	15.1	15.3
[00257] % O_2 (15 mph)	0.0	0.0
[00258] % O_2 (25 mph)	0.0	0.0
[00259] ppm HC (15 mph)	1	6
[00260] ppm HC (25 mph)	1	7
[00261] % CO (15 mph)	0.00	0.01
[00262] % CO (25 mph)	0.00	0.01
[00263] ppm NO (15 mph)	0	19
[00264] ppm NO (25 mph)	0	44

[00265] As can be seen from Table 13, the fuel composition of embodiment 9 performs significantly better than unleaded fuel purchased at a gas station with respect to all of the monitored emissions.

[00266] Embodiment 10

[00267] A fuel blend of the following composition was made using the following constituents measured by volume percent: gasoline (48% SR), ethanol (38%), isobutanol (4%) and MTBE (10%). The order of mixing each material is arbitrary.

[00268] Emissions Comparison 1

[00269] An ASM Emission Test was conducted using the fuel blend of Embodiment 10. The test was conducted on a 2002 Toyota Camry 2.4L L4 EFI DOHC 16V engine V.I.N. # 4T1BE32KX2U5200144 with an air conditioner operating during the test. The vehicle odometer read just over 11,500 miles. Emissions testing was conducted and the results are displayed below in Table 14.

[00270] Table 14	Embodiment 10	Conventional Gasoline
[00271] % CO_2 (15 mph)	15	15.2
[00272] % CO_2 (25 mph)	15.1	15.3
[00273] % O_2 (15 mph)	0	0.0
[00274] % O_2 (25 mph)	0	0.0

[00275]	ppm HC (15 mph)	1	6
[00276]	ppm HC (25 mph)	0	7
[00277]	% CO (15 mph)	0	0.01
[00278]	% CO (25 mph)	0	0.01
[00279]	ppm NO (15 mph)	0	19
[00280]	ppm NO (25 mph)	0	44

[00281] As can be seen from Table 14, the fuel composition of embodiment 10 performs significantly better than unleaded fuel purchased at a gas station with respect to all of the monitored emissions.

[00282] Emissions Comparison 2

[00283] An ASM Emission Test was conducted using the fuel blend of Embodiment 10. The test was conducted on a 1985 Nissan Truck 2.4L L4 EFI engine V.I.N. # JN6ND01S1FW007861 without an air conditioner operating during the test. The vehicle odometer read just over 105,200 miles. Emissions testing was conducted and the results are displayed below in Table 15.

[00284] Table 15	Embodiment 10	Conventional Gasoline

[00285] % CO_2 (15 mph)	14.6	14.5
[00286] % CO_2 (25 mph)	14.6	14.5
[00287] % O_2 (15 mph)	0.4	0.3
[00288] % O_2 (25 mph)	0.4	0.5
[00289] ppm HC (15 mph)	27	47
[00290] ppm HC (25 mph)	30	49
[00291] % CO (15 mph)	0.42	0.44
[00292] % CO (25 mph)	0.27	0.31
[00293] ppm NO (15 mph)	1182	2229
[00294] ppm NO (25 mph)	1241	2460

[00295] In the jurisdiction in which this emissions test was performed, the vehicle failed to satisfy the emissions requirements during the test when conventional obtained unleaded gasoline (*i.e.* conventional fuel) was used. As seen from Table 15, the fuel composition of embodiment 10 performed

significantly better in this vehicle so that the vehicle met the emissions requirements during the second test.

[00296] The vehicle was road tested before and after emissions testing using in town (frequent stops) and freeway driving. No engine knock, overheating or engine misfiring was observed. The outside air temperature while driving the truck averaged 40 degrees at an elevation of approximately 4600 ft. above sea level.

[00297] Emissions Comparison 3

[00298] An ASM Emission Test was conducted using the fuel blend of Embodiment 10. The test was conducted on a 2002 Dodge Caravan 2.4L L4 SMPI DOHC 16V engine V.I.N. # 1B4GP15B12B555263 without an air conditioner operating during the test. The vehicle odometer read just over 14,300 miles. Emissions testing was conducted and the results are displayed below in Table 16.

[00299] Table 16	Embodiment 10	Conventional Gasoline
[00300] % CO_2 (15 mph)	15.1	15.2
[00301] % CO_2 (25 mph)	15.0	15.2
[00302] % O_2 (15 mph)	0.0	0.1
[00303] % O_2 (25 mph)	0.0	0.1

[00304]	ppm HC (15 mph)	2	0
[00305]	ppm HC (25 mph)	1	0
[00306]	% CO (15 mph)	0.00	0.00
[00307]	% CO (25 mph)	0.00	0.01
[00308]	ppm NO (15 mph)	2	9
[00309]	ppm NO (25 mph)	2	18

[00310] As can be seen from Table 16, the fuel composition of embodiment 10 performs equally or better than the conventional unleaded fuel.

[00311] The vehicle was road tested before and after emissions testing at in-town (frequent stops) and freeway driving speeds up to 95 miles per hour with the air conditioner on and off. No engine knock, overheating or engine misfiring was observed. The outside air temperature while driving the Caravan averaged 40 degrees at an elevation of approximately 4600 ft. above sea level.

[00312] Embodiment 11

[00313] A fuel blend of the following composition was made using the following constituents measured by volume percent: gasoline (43% FR), ethanol (37%), isobutanol (13.5%) and MTBE (6.5%). The order of mixing each material is arbitrary.

[00314] Emissions Comparison 1

[00315] An ASM Emission Test was conducted using the fuel blend of Embodiment 11. The test was conducted on a 2003 Lincoln Town 4.6L SEFI OHC V8 engine V.I.N. # 1LNHM81W53Y630025 without an air conditioner operating during the test. The vehicle odometer read just over 750 miles. Emissions testing was conducted and the results are displayed below in Table 17.

[00316] Table 17	Embodiment 11	Conventional Gasoline
[00317] % CO_2 (15 mph)	15.2	15.3
[00318] % CO_2 (25 mph)	15.2	15.3
[00319] % O_2 (15 mph)	0.0	0.0
[00320] % O_2 (25 mph)	0.0	0.0
[00321] ppm HC (15 mph)	4	0
[00322] ppm HC (25 mph)	0	1
[00323] % CO (15 mph)	0.00	0.00
[00324] % CO (25 mph)	0.00	0.00

[00325] ppm NO (15 mph)	0	11
[00326] ppm NO (25 mph)	3	5

[00327] As can be seen from Table 17, the fuel composition of embodiment 11 performs equally or better than the conventional unleaded fuel.

[00328] The vehicle was road tested before and after emissions testing at in-town (frequent stops) and freeway driving speeds up to 110 miles per hour with the air conditioner on and off. No engine knock, overheating or engine misfiring was observed. The outside air temperature while driving the Lincoln averaged 85 degrees at an elevation of approximately 4600 ft. above sea level.

[00329] Emissions Comparison 2

[00330] An ASM Emission Test was conducted using the fuel blend of Embodiment 11. The test was conducted on a 2003 Lincoln Town 4.6L SEFI OHC V8 engine V.I.N. # 1LNHM81W53Y630025 without an air conditioner operating during the test. The vehicle odometer read just over 750 miles. Emissions testing was conducted and the results are displayed below in Table 18.

[00331] Table 18	Embodiment 11	Conventional Gasoline
[00332] % CO_2 (15 mph)	15.0	15.3
[00333] % CO_2 (25 mph)	15.0	15.3

[00334] % O_2 (15 mph)	0.0	0.0
[00335] % O_2 (25 mph)	0.0	0.0
[00336] ppm HC (15 mph)	1	0
[00337] ppm HC (25 mph)	0	1
[00338] % CO (15 mph)	0.00	0.00
[00339] % CO (25 mph)	0.00	0.00
[00340] ppm NO (15 mph)	0	11
[00341] ppm NO (25 mph)	1	5

[00342] As can be seen from Table 18, the fuel composition of embodiment 11 performs significantly better than unleaded fuel purchased at a gas station with respect to all of the monitored emissions.

[00343] The vehicle was road tested before and after emissions testing at in-town (frequent stops) and freeway driving speeds up to 110 miles per hour with the air conditioner on and off. No engine knock, overheating or engine misfiring was observed. The outside air temperature while driving the **Lincoln** averaged 85 degrees at an elevation of approximately 4600 ft. above sea level.

[00344] Engine performance comparisons were conducted with some of the fuel blends. For these comparisons, an MD Mustang Dynamometer was utilized.

[00345] Performance Test 1

[00346] A performance test was conducted on a 2002 Toyota Camry 2.4L L4 EFI DOHC 16V engine V.I.N. # 4T1BE32K02U067201. The vehicle odometer read just over 17600 miles. The vehicle weighed 3334 pounds. The vehicle was first tested using regular unleaded 87-octane gasoline obtained from a retail Chevron station. After the test was conducted, the commercial fuel was replaced with a fuel blend of Embodiment 10. The vehicle was again tested and the results recorded. Referring to **Fig. 1**, the results of the performance test in terms of measured horsepower are depicted in a chart. The X axis **101** represents the engine RPM (revolutions per minute) and the Y axis **102** represents the observed horsepower. The data series **103** (a solid line) represents measurements for the fuel blend of embodiment 10. The data series **104** (a dotted line) represents measurements for conventional 88 octane gasoline. The data series are additionally described in key **105**. Referring to **Fig. 2**, the results of the performance test in terms of measured torque are depicted in a chart. The X axis **201** represents the engine RPM (revolutions per minute) and the Y axis **202** represents the observed torque in units of foot-lbs. The data series **203** (a solid line) represents measurements for the fuel blend of embodiment 10. The data series **204** (a dotted line) represents measurements for conventional 88 octane gasoline. The data series are additionally described in key **205**.

[00347] Both **Fig. 1** and **Fig. 2** show that the fuel blend of embodiment 10 performs with equal or better horsepower and torque output compared with conventional gasoline.

[00348] Performance Test 2

[00349] An additional dynamometer test was conducted using the fuel blend of Embodiment 10. The test was conducted on a 2002 Dodge Caravan 2.4L L4 SMPI DOHC 16V engine V.I.N. # 1B4GP15B12B555263. The vehicle odometer read just over 14,300 miles. The vehicle weighed 3908 lbs. The vehicle was first tested using regular unleaded 87 octane gasoline obtained from a retail Chevron station. After the test was conducted, the commercial fuel was replaced with a fuel blend of Embodiment 10. The vehicle was again tested. Referring to **Fig. 3**, the results of the performance test in terms of measured horsepower are depicted in a chart. The X axis **301** represents the engine RPM (revolutions per minute) and the Y axis **302** represents the observed horsepower. The data series **303** (a solid line) represents measurements for the fuel blend of embodiment 10. The data series **304** (a dotted line) represents measurements for conventional 85 octane gasoline. The data series are additionally described in key **305**. Referring to **Fig. 4**, the results of the performance test in terms of measured torque are depicted in a chart. The X axis **401** represents the engine RPM (revolutions per minute) and the Y axis **402** represents the observed torque in units of foot-lbs. The data series **403** (a solid line) represents measurements for the fuel blend of embodiment 10. The data series **404** (a dotted line) represents measurements for conventional 85 octane gasoline. The data series are additionally described in key **405**.

[00350] Both **Fig. 3** and **Fig. 4** show that the fuel blend of embodiment 10 performs with equal or better horsepower and torque output compared with conventional gasoline.

[00351] Embodiment 12

[00352] A fuel blend of the following composition was made using the following constituents measured by weight percent: Naphtha (46.3%), ethanol (39.8%), and isobutanol (4.2%) and MTBE (9.7%). The order of mixing each material is arbitrary.

[00353] Emissions Comparison 1

[00354] An ASM Emission Test was conducted using the fuel blend of Embodiment 12. The test was conducted on a 2002 Toyota Camry 2.4L L4 EFI DOHC 16V engine V.I.N. # 4T1BE32K72U592109 with an air conditioner operating during the test. The vehicle odometer read just over 13,700 miles. Emissions testing was conducted and the results are displayed below in Table 19.

[00355] Table 19	Embodiment 12	Conventional Gasoline
[00356] % CO_2 (15 mph)	14.7	15.5
[00357] % CO_2 (25 mph)	14.7	15.5
[00358] % O_2 (15 mph)	0.0	0.0
[00359] % O_2 (25 mph)	0.0	0.0
[00360] ppm HC (15 mph)	0	1
[00361] ppm HC (25 mph)	0	7
[00362] % CO (15 mph)	0.00	0.01
[00363] % CO (25 mph)	0.00	0.02

[00364] ppm NO (15 mph)	3	19
[00365] ppm NO (25 mph)	5	20

[00366] As can be seen from Table 19, the fuel composition of embodiment 12 performs significantly better than unleaded fuel purchased at a gas station with respect to all of the monitored emissions.

[00367] The vehicle was road tested before and after emissions testing at in-town (frequent stops) and freeway driving speeds up to 120 miles per hour with the air conditioner on and off. No engine knock, overheating or engine misfiring was observed. The outside air temperature while driving the Camry averaged 42 degrees at an elevation of approximately 4600 ft. above sea level.

[00368] Emissions Comparison 2

[00369] An ASM Emission Test was conducted using the fuel blend of Embodiment 12. The test was conducted on a 2002 Toyota Camry 2.4L L4 EFI DOHC 16V engine V.I.N. # 4T1BE32K72U592109 without an air conditioner operating during the test. The vehicle odometer read just over 13,750 miles. Emissions testing was conducted and the results are displayed below in Table 20.

[00370] Table 20	Embodiment 12	Conventional Gasoline
[00371] % CO_2 (15 mph)	14.7	15.5

[00372]	% CO_2 (25 mph)	14.8	15.5
[00373]	% O_2 (15 mph)	0.0	0.0
[00374]	% O_2 (25 mph)	0.0	0.0
[00375]	ppm HC (15 mph)	0	0
[00376]	ppm HC (25 mph)	0	0
[00377]	% CO (15 mph)	0.00	0.02
[00378]	% CO (25 mph)	0.00	0.01
[00379]	ppm NO (15 mph)	4	35
[00380]	ppm NO (25 mph)	7	29

[00381] As can be seen from Table 20, the fuel composition of embodiment 12 performs significantly better than unleaded fuel purchased at a gas station with respect to all of the monitored emissions.

[00382] The vehicle was road tested before and after emissions testing at in-town (frequent stops) and freeway driving speeds up to 120 miles per hour with the air conditioner on and off. No engine knock, overheating or engine misfiring was observed. The outside air temperature while driving the Camry

averaged 42 degrees at an elevation of approximately 4600 ft. above sea level.

[00383] Embodiment 13

[00384] A fuel blend of the following composition was made using the following constituents measured by volume percent: naphtha (45.5%), ethanol (39.4%), and isobutanol (6.2%) and MTBE (8.9%). The order of mixing each material is arbitrary. This blend had a Research Octane Number (RON) of 100.

[00385] Emissions Comparison 1

[00386] Emissions testing was conducted on the blend of embodiment 13 by NKKK labs in Japan. The testing conducted by NKKK used relevant JIS (Japanese Industry Standards) methods comparable to ASTM methods previously referenced and comparable to the emissions testing performed in the United States. The NKKK lab has a JISQ9001certification which is identical to an ISO 9001 certification. A chemiluminescence Detector (CLD) to measure NO_x emissions. CO emissions were conducted using non-dispersive infrared (NDIR) detectors. HC levels were monitored using gas chromatography. CO_2 emissions were monitored using NDIR detectors as well. The results of the testing are displayed below in Table 21.

[00387] Table 21	Embodiment 13	Conventional Gasoline	Difference in g/km traveled
[00388] % CO	0.43 ppm	2.41 ppm	0.038 g/km
[00389] HC	2.06 ppm	2.30 ppm	0.003 g/km

[00390]	NO_x	0.03 ppm	1.43 ppm	0.042 g/km
[00391]	CO_2	0.038 %	0.812 %	231.3 g/km

[00392] As can be observed from the data in Table 21, the fuel blend derived from embodiment 13 produces much less pollution by products than conventional gasoline as emissions were lower in all categories.

[00393] Emissions Comparison 2

[00394] An additional emissions test was conducted on the blend of embodiment 13 by NKKK labs in Japan. The results of the testing are displayed below in Table 22.

[00395]	Table 22	Embodiment 13	Conventional Gasoline	Difference in g/km traveled
[00396]	% CO	0.63 ppm	6.97 ppm	0.122 g/km
[00397]	HC	2.09 ppm	2.32 ppm	0.003 g/km
[00398]	NO_x	0.02 ppm	0.78 ppm	0.023 g/km
[00399]	CO_2	0.042 %	0.837%	238.9 g/km

[00400] As can be observed from the data in Table 22, the fuel blend derived from embodiment 13 produces much less pollution by products than conventional gasoline as emissions were lower in all categories.

[00401] In another aspect of the fuel blends, the constituents may be expressed in terms of a range of weight or volume percents. In one embodiment, the gasoline portion may be present at a level between about 12 percent and about 45 percent, alcohol(s) may be present in an amount between about 15 percent and about 85 percent, ether(s) may be present in an amount between about 3 percent and about 30 percent.

[00402] The compositions of the present invention may be formulated as summer and winter blends having T10 and T90 values as measured by ASTM-D86 within ASTM specifications for summer and winter fuel blends. The winter blend compositions are significantly more volatile than conventional gasoline to aid cold weather starting. The T90 values indicate the amount of heavy-weight components in the fuel. These substances are considered to be a primary source of unburned hydrocarbons during the cold start phase of engine operation. The lower values of heavy-weight components in the compositions also indicate superior emissions performance.

[00403] In another aspect of fuel blends, methods for manufacturing the fuel blends are provided. Referring to **FIG. 5**, a flow chart depicts the steps of a method for preparing some of the fuel blends. The steps include obtaining an alcohol feed 501, obtaining a naphtha feed 502, obtaining an ether feed 503, selecting a blending technique 504 for blending the alcohol feed **501** with the naphtha feed **502** and the ether feed **503**, performing the selected blending technique **505** to all feeds, and finally storing the blended fuel **506** in a storage tank for distribution. In one example, the alcohol feed includes one type of alcohol. In another example, the alcohol feed includes a mixture of more than one type of alcohol. In still another example, the ether feed includes one type of ether. In yet another example, the ether feed includes a mixture of more than one type of ether. An example of a blending technique includes turbulent blending arising from either a static mixer or machinery designed tin induce turbulence.

[00404] In another example of a method for manufacturing the fuel blends, referring to **FIG. 6**, a flow chart depicts the steps of a method for preparing some of the fuel blends. The steps include obtaining an alcohol feed **601**, obtaining a naphtha feed **602**, selecting a blending technique **603** for blending the alcohol feed **601** with the naphtha feed **602**, performing the selected blending technique **604** to all feeds, and finally storing the blended fuel **605** in a storage tank. In one example, the alcohol feed includes one type of alcohol. In another example, the alcohol feed includes a mixture of more than one type of alcohol. In still another example, the ether feed includes one type of ether. In yet another example, the ether feed includes a mixture of more than one type of ether. An example of a blending technique includes turbulent blending arising from either a static mixer or machinery designed tin induce turbulence.

[00405] While the fuel blends and methods of blending have been described and illustrated in conjunction with a number of specific configurations, those skilled in the art will appreciate that variations and modifications may be made without departing from the principles herein illustrated, described, and claimed. The present invention, as defined by the appended claims, may be embodied in other specific forms without departing from its spirit or essential characteristics. The fuel blends and methods described herein are to be considered in all respects as only illustrative, and not restrictive. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.